The Effect of Waterer Color and Frequency of Waterer Cleaning on Sheep Water Intake

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ABSTRACT

Water is an essential nutrient across animal species, and livestock species must maintain hydration to promote their health and productivity. Water consumption, however, is influenced by many factors, and producers must practically control as many factors as possible in order to encourage livestock's water consumption. Encouraging water consumption begins with the waterer itself, and there are waterer factors that producers have complete control over. The objective of these experiments was to investigate two factors of the waterer that producers can control: color of waterers and how frequently waterers are cleaned. I hypothesized that the sheep would prefer the blue waterer in the color trials and the waterer cleaned daily in the cleaning frequency trails. Three waterers (flat-backed, 5-gallon stock buckets) per pen of sheep (n = 4) were utilized for both procedures. Waterer weights were recorded every 12 hours to determine the amount of water consumed. For color preference, a yellow, blue, and black waterer were all placed in each pen. For cleaning frequency preference, three waterers of identical color were placed in each pen. Different cleaning schedules were implemented on each waterer (Waterer 1: once daily; Waterer 2: once every fourth day; Waterer 3: once every seventh day). When designated to be cleaned, the waterer was emptied, removed of debris using a scrub brush, refilled, and returned to pens. Waterers were refilled every 12 hours regardless of cleaning. Analysis for color accounted for fixed effect of color and random effects of pen, bucket position, and time (AM/PM). The consumed twice as much water ($P = 0.02$) from blue or yellow waterers (1.327 L/head/day, 1.535 L/head/day) compared to the black waterer (0.790 L/head/day). Analysis for cleaning frequency preference accounted for fixed effects of day, treatment, treatment × day interaction and random effects of pen, week, position, and time (AM vs PM), with a repeated effect of day. Sheep preferred ($P < 0.0001$) the waterer that was cleaned once per

day (2.680 L/head/day) compared to waterers cleaned every seventh day (0.795 L/head/day). Sheep did not find waterers cleaned every fourth day (1.393 L/head/day) less preferable than waterers cleaned daily (2.680 L/head/day) nor more preferable than waterers cleaned every seventh day (0.795 L/head/day, $P > 0.10$). These results suggest that sheep consume more water from colored waterers and from waterers that are cleaned more frequently, and producers should utilize waterer colors such as yellow or blue and clean their waterers every 1 to 4 days.

INTRODUCTION

Water as a Nutrient

Water is arguably the most important nutrient for all animals because it is vital to maintain normal biological functioning, including temperature regulation and biochemical reactions within the body. Water is also a solvent that allows ionization within the protoplasm of cells, transports digesta and solutes, dilutes bodily fluids so products within the fluids can freely move, and is a substrate in hydrolysis to break down molecules for bodily use (Pond et al., 2004). Water accounts for up to 70% of the body weight of livestock on a fat-free basis (Pond et al., 2004) depending on age, prevalence of fat, and overall physical condition. There is also a constant loss of water through respiration, environmental changes, sweating, defecation, urination, and more, thus driving the need to ensure proper water intake to replace these losses (Wakchaure et al., 2015). External stressors due to extreme temperatures, for example, can delegate a substantial amount of energy towards temperature regulation that could otherwise be utilized for production, but properties of water allow for efficient heat exchange and temperature maintenance when the animal is hydrated. Water has a high specific heat, high latent heat of vaporization, and high thermal conductivity, which aid in maintaining internal temperature through storing heat and preventing rapid heat loss (Pond et al., 2004). For all of the aforementioned reasons, dehydration can severely impact various desired areas of performance, including growth rate and milk production.

Without adequate water intake, body temperature is more susceptible to increases in warmer environments because there is not water available to evaporate and cool the body. Furthermore, water restriction will cause urine and fecal excretion to decrease substantially, followed by rapid body weight loss, kidney failure, and possibly death. Dehydration in sheep can also cause an increased respiration rate, increased blood concentration, nausea, and bad temperament (Pond et al., 2004). Poor temperament in animals can lead to poor handling and pose threats to the animals themselves, other animals, and their handlers. This poor temperament can increase their likelihood of sustaining injuries or injuring a handler or other animal around them. It is also possible for the animals to become increasingly stressed during handling, and the possibility of both injuries and stress can decrease the animal's overall welfare.

Physiological condition and stage of production also contribute to an animal's water intake. Specifically, with sheep, a dry ewe consumes eight liters of water per day, compared to a lactating ewe that would consume eleven liters of water per day. During gestation, a pregnant ewe will increase her water intake by 126% from the first to fifth month of gestation. The water intake of a lactating ewe ranges from about eight liters to twenty liters. The lamb itself will consume two to four liters, and a ram needs approximately eleven liters of water (El Mahdy, 2019). Reproduction and breeding are additionally important components in animal agriculture. Limited water decreases food intake, which then causes a lack of ovarian follicular growth and decreases reproductive viability (El Mahdy, 2019). Directly, decreased water consumption reduces milk yield, which subsequently affects the health of the neonate and the profitability of the animals whose milk is intended to be sold. The fetus and placenta also rely on water to maintain a hospitable environment and protect from reproductive problems (El Mahdy, 2019). When completely depriving goats of water for 48 hours in both their early and mid-lactation, their milk volume decreased. When the goats were deprived of food, however, their milk volume decreased by a smaller magnitude compared to water deprivation, indicating the importance of water consumption as it relates to lactation milk volume (Dahlborn, 1987). The aforementioned impacts on physiological functioning make water quality and quantity resource-based measures of animal welfare. Welfare assessments may include water availability (i.e. ease of access) and contamination of water (Richmond et al., 2017). Findings of restricted water, whether through blatant deprivation or through providing inadequate water sources that are not clean or not easily accessible, can directly and negatively affect animal welfare.

The Sheep Eye and Color Discrimination

One possibility for encouraging water consumption is manipulating the water apparatus itself. Previous studies on the waterers themselves have demonstrated that different apparatuses can affect an animal's consumption. A study concerning water bowl preferences in horses demonstrated that the shape and mechanism of releasing water in the waterers affected how much water the horses consumed from each type of watering system, and the results revealed that the horses had a strong preference for one mechanism over the other and consumed practically no water from one type. The researchers concluded that the main factor that influenced the horses' choice was the large, open shape of one bowl over the others (Krawczel et al., 2006). This demonstrates that shape of the waterers themselves can be highly influential in water consumption in animals. In another study, the preference of color of water troughs in cows was studied, resulting in the suggestion that the color red, compared to gray and green, could be an aversive color to cows (Lemos Teixiera et al., 2017). This may or may not be accurate for sheep, but this demonstrates an opportunity to explore preference for or potential aversion to colors for sheep. Both of the aforementioned studies point towards the influence of the water container itself in a livestock animal's water consumption, but no studies to date have researched this in sheep. Based on research suggesting that sheep can discriminate between color, utilizing color for waterers may be an advantageous practice for producers to encourage water consumption.

Studies of the sheep eye support the notion that sheep have the structures necessary to see at least some color. In a study conducted by Jacobs et al. (1998), it was cited that the sheep's rod to cone ratio ranges from 30:1 to 40:1, and spectral sensitivity tests resulted in the identification of two cone types in sheep. These findings support the idea that sheep have dichromatic vision. Dichromatic vision is defined as having two cone types that process color within a spectrum that is based on the sensitivity of the cones (VerCauteren and Pipas, 2003). Sheep also have prominent tapeta (Jacobs et al., 1998), which reflect light to allow animals to better see in low-light conditions, so sheep may have a higher sensitivity to brightness and varying levels of light. This conclusion is supported by additional studies by Shinozaki et al. (2010) that have specifically focused on the varying structures, such as rods and cones, that affected sheep vision. The researchers concluded that sheep eyes have adapted for diurnal activity with some low-light environments, and their eyes allow for a 290-degree visual field that allows them to scan their environment for predators and better process colors for food and resources without moving their head or eyes (Shinozaki et al., 2010). Again, this study offers additional support for the presence of dichromatic vision and the collection of rods and cones within the eye, which provides evidence of the advantageous nature of their form of vision. The full extent to which sheep can see color, however, is not fully conclusive, but there is strong data suggesting that sheep color vision is dichromatic.

Studies have concluded that species other than sheep, such as deer, also possess dichromatic vision that allows for color discrimination (VerCauteren and Pipas, 2003). Specifically, one study conditioned four female fallow deer to investigate their ability to discriminate between green and gray, including variations of brightness of both colors in order to decrease the possibility of achromatic factors contributing to their ability to learn, and the researchers concluded that deer can generally recognize some color (Birgersson and Forkman, 2001). A review concerning the preceding studies of eye color in deer established that deer view color in blue to yellow-green, and deer have the ability to discriminate between colors of longer wavelengths, like red, and medium wavelengths, like green (VerCauteren and Pipas, 2003). Evidence of dichromatic vision subsequently provides insight as to how these animals perceive their world and the colors associated with it.

Past studies support that sheep are able to discriminate colors, as demonstrated in an experiment by Alexander and Stevens (1979) in which the researchers began by coloring lambs with certain colors or shades of gray and allowed the ewes of each lamb to interact with their lambs for a few days. After those days in which the ewes were able to acclimate to their lamb's color, the experimenters separated the lamb from the ewe and utilized a set of lambs not belonging to the ewe, one of which had the color of the original lamb, to see if the ewe could recognize her lamb based on the familiar color (Alexander and Stevens, 1979). Ewes were more successful at recognizing their lambs if the lambs were red, orange, yellow, or white, but did not recognize blue, green, shades of gray, or black lambs (Alexander and Stevens, 1979), which suggests that the ewes can recognize some variation of color.

Further studies suggest that sheep can distinguish between opposite colors, specifically green versus red and yellow versus blue (Tanaka et al., 1989b), and another study regarding the determination of a sheep's ability to discriminate between similar colors offers the possibility of color having a significant impact on sheep in their daily lives (Tanaka et al., 1989a). Within the first study conducted by Tanaka et al. (1989b), ewes, and later 5-month-old twin lambs, were tasked with discriminating between a colored card and a gray card with the same luminosity. The ewe was placed into a T maze with a colored (red, green, or blue) and gray card. Accessible feed was behind the colored card, but the feed behind the gray card was covered in wire. The second experiment utilized lambs that were conditioned to press a switch for feed, and the lambs were tasked with choosing the card (red versus gray, green versus gray, blue versus gray, red versus green, and yellow versus blue) that led to the feed reward. The results demonstrated that the ewes and lambs were able to distinguish between the color presented and the gray, with the exception that one lamb struggled to discriminate green and gray. This same experiment offered a red versus green and yellow versus blue component for the twin lambs, and both lambs were able to learn the differences between the colors in about one-third of the sessions compared to the color versus gray discrimination tests (1989b). Initial promise in a sheep's ability to discern between colors began here, but the fact that only two lambs were tested leads to the need for more data within the subject. Tanaka et al. (1989a) then completed another experiment that focused on discrimination between colors as with the two lambs of the previous study. A different set of twin lambs were used compared to the prior study, but of the same age (1989a). These two lambs were able to differentiate between many different colors except for the most similar of colors that the experimenters utilized, and the researchers found that the lambs demonstrated a significant difference in the amount of time it took for them to reach the experimental criterion, which was a 70% accuracy rate in distinguishing between the cards after 30 trials (1989a). Tanaka et al. (1989a) attributed the difference to the possibility of the effect of rearing differences, citing that the lamb who took more time to learn the task compared to the other lamb demonstrated more comfort within its flock while the faster lamb, who had been raised by humans rather than a flock, appeared more comfortable with the human experimenters. When tested on the ability to discriminate between simple and compound colors, sheep were able to perform the most complex tasks within these studies (Morton and Avanzo, 2011), which supports both the sheep's ability to learn cognitively challenging tasks and perceive differences in color.

Water as a Nutrient and Water Quality

Deviations in water quality can subsequently alter an animal's water consumption, thus decreasing their productivity and welfare. Pathogenic microorganisms, along with algae, oils, and various chemicals can be toxic and decrease water palatability for the animal. Increased salt concentrations may increase water consumption but impose toxic effects on the animal, such as diarrhea (Pond et al., 2004). This also holds true for nitrate concentrations. Nitrates and nitrites exist in water due to its presence in the surrounding environment, and toxic nitrite concentrations can reduce the blood's ability to carry oxygen by affecting the iron in hemoglobin (Pond et al., 2004). In an outdoor setting in which researchers compared water from a clean source versus drinking directly from a pond, the weight gain of heifers was 23% higher in those that drank the clean water (Wakchaure et al., 2015). There exists a substantial effect of water quality on productivity in the above experiment because both sets of heifers had access to ample water yet their growth vastly differed, apparently due to source. The components of pond water can impact the animal's desire to consume from it despite its availability, thus decreasing overall consumption. Pond water contains plant matter, manure runoff, possible pathogens, and other components that can mirror that of unclean drinking water within intensive systems, demonstrating that these growth differences can occur in water systems that are not properly managed even indoors. Water quality can greatly affect production animals, and it is important to consider the components of water that can influence water quality and subsequent consumption.

The main factors determining water quality are salinity, pH, and potentially toxic components (Lardy et al., 2008; Wakchaure et al., 2015). Manure serves as a large contributor to unclean water, altering both the taste and smell of the water and decreasing intake. Manure also aids in the proliferation of other bacteria and fungi, transfers pathogens and parasites into the water, and may harm the health of the animal that drinks from the source (Umar et al., 2014). The effect on the animal varies from decreased productivity to fatal diseases. Algae growth in water can specifically produce aromas that dissuade animals from consuming the water, and calves that had access to clean water versus water with substantial algae growth gained 9% more weight (Umar et al., 2014). Purified water, however, is also undesirable for sheep to consume because it does not contain salts and gases that can increase palatability (Lardy et al., 2008), meaning that a completely clean water container may potentially decrease the sheep's consumption.

General recommendations advise that water troughs are cleaned frequently (Lardy et al., 2008), but this frequency has not been defined. Producers then need to test a variety of time periods between cleaning, possibly neglecting apparently clean water that sits within pens for extensive periods of time and inadvertently causing insufficient water consumption. If a producer can understand the best cleaning frequency of their water apparatuses, then producers can better aid in ensuring that animals consume enough water for daily functions and optimum production. Researchers, on the other hand, can experimentally determine what frequency water containers should be cleaned, thus eliminating the frustrations of producers in testing the frequency for themselves. Besides a lack of concrete frequency recommendations, cleaning protocols are generally based on producer preferences. For instance, one protocol explained that one should scrub the empty trough using detergent and a stiff-bristled brush, rinse the trough with water, and then add diluted bleach (two to three ounces for 150 gallons of water) to prevent algae growth (Garavet 2019). Proper cleaning procedures, including frequency, are vital in providing proper water access to livestock, and more research is necessary to provide evidence-based management practices on the routine cleaning and disinfection of waterers.

Objectives and Hypotheses

The first objective of this study was to investigate if sheep have a preference for their waterer color when comparing yellow, blue, and black waterers. It was hypothesized that the sheep would prefer to drink from the blue waterers. The second objective of this study was to investigate if sheep have a preference for how often their waterers are cleaned when comparing waterers that are cleaned daily, every fourth day, and every seventh day. It was hypothesized that the sheep would prefer to drink from the waterers cleaned daily.

METHODS AND MATERIALS

Data for this experiment were collected within the sheep barn on Waterman Dairy Farm operated by The Ohio State University. Data were collected from February 22nd, 2021 through March 14th, 2021, and procedures were conducted in accordance with IACUC guidelines (Animal Use Protocol Number 2021A00000007).

The sheep utilized in the experiment were different ages and sexes based on their pen, and pen numbers corresponded to those designated by the research location. Pens 1 and 7 consisted of 5 fall-born ram lambs each. Pen 3 consisted of 4 ewes that had given birth within the previous two weeks and their 3 lambs. Pen 5 consisted of 3 pregnant ewes that were expected to lamb in early April.

This experiment studied the effects of two characteristics of waterers: color and frequency of cleaning. Three waterers (flat-backed, 5-gallon stock buckets) per pen ($n = 4$) of sheep were utilized for both procedures, and they were placed into the pen side by side in order to eliminate a location bias for water consumption. The waterers were rotated one position to the right every 12 hours after weight measurements were taken. The waterers were filled to a designated line, and an initial weight was recorded. After 12 hours, the waterers were removed from the pen, and their final weights were recorded. The difference in weight was equated to liters of water consumed per pen, and this number was further divided to determine the average amount of water consumed per head within the pen.

Color Preference

For the study of color preference, three different colored waterers (blue, yellow, and black) were used. Two weeks prior to data collection, one waterer of each color was placed into the pens in order to diminish the novelty of the items to the sheep. These colors were determined based on the evidence related to sheep having dichromatic vision and a previous study that demonstrated that sheep have the ability to distinguish between opposite colors such as yellow and blue (Jacobs et al., 1998; Tanaka et al., 1989b). A waterer of each color was utilized for the 1-week trial period. After collecting the waterers' final weights, each waterer was removed of water and debris, scrubbed with a bristled brush, refilled with water, and returned to the pen.

Cleaning Frequency

For the study of cleaning frequency, each of the three waterers was subjected to a different cleaning schedule that corresponded to a daily, twice weekly, and once weekly. The three waterers in each pen were of identical color. Waterer 1 was cleaned every morning in the seven-day trail period. Waterer 2 was cleaned the morning of Day 4 of the trial period and again the night of Day 7. Waterer 3 was cleaned the night of Day 7. When designated to be cleaned, the waterer was removed of water and debris, scrubbed with a bristled scrub brush, refilled with water, and returned to the pen. The waterers were refilled every 12 hours regardless of cleaning.

Behavior: Individual Preferences

In order to evaluate if individual sheep exhibited preferences for either factor, behavioral data were collected twice per week by a single observer. One set of observations per week occurred during the morning (between 8-10am), and the other set of observations occurred during the late evening/night (between 8-10pm). This was completed through scan sampling with 30 second intervals for a total of 20 minutes per pen. The primary behavior of interest was drinking at each waterer, but data were also collected regarding eating, environmental manipulation, and interactions between pen mates (Table 1). Data were collected for each of the sheep except for the 3 lambs in Pen 3, and the sheep were labeled A-Q.

Table 1: The ethogram utilized for behavioral observations. Behavioral data were collected using scan sampling every 30 seconds for 20 minutes per pen, and observations were conducted twice per week: once in the morning (between 8-10 am) and once in the late evening (8-10 pm).

Ethogram	
Behavior + Description	Key
Drinking: drinking water from any bucket in the pen; add bucket ID next to ethogram code	dr
Eating: consuming feed from feeders	et
Inactive: lying or standing without any other significant behaviors	in
Agonistic interaction: Engaged in behaviors such as butting, threatening, avoiding, chasing, or clashing.	ag
Non-Agonistic interaction: Engaging in positive/neutral social behaviors such as rubbing, grooming, sniffing, etc.	na
Environmental manipulation: Rubbing, nosing, or otherwise engaging with different structures in the environment	ev
Human interaction: actively engaging with or visually following researchers or other people in the area	hi
Locomotion: walking or running around pen	lo
Other: Any behavior that does not fit under the above categories	ot

Statistical Analysis

Statistical analysis was completed using SAS v9.4 (Cary, NC, USA). For the model of the effect of color on water intake, the fixed effect within the study was bucket color, and the random effects were position, pen, and feeding time (AM/PM). The statistical model for cleaning included the fixed effects of day, treatment, treatment × day interaction and random effects of pen, week, position, and time of day (AM vs PM), with a repeated effect of day using a first-order autoregressive covariate structure. Significance was declared at $P < 0.05$, trends at $0.05 \leq P < 0.10$, and differences considered non-significant at $P > 0.10$.

RESULTS AND DISCUSSION

Color Preference

Analysis for color preference ($P = 0.02$) demonstrated that the sheep were twice as likely to drink from either the blue or yellow waterers (1.327 L/head/day, 1.535 L/head/day) compared to the black waterer (0.790 L/head/day) (Figure 1).

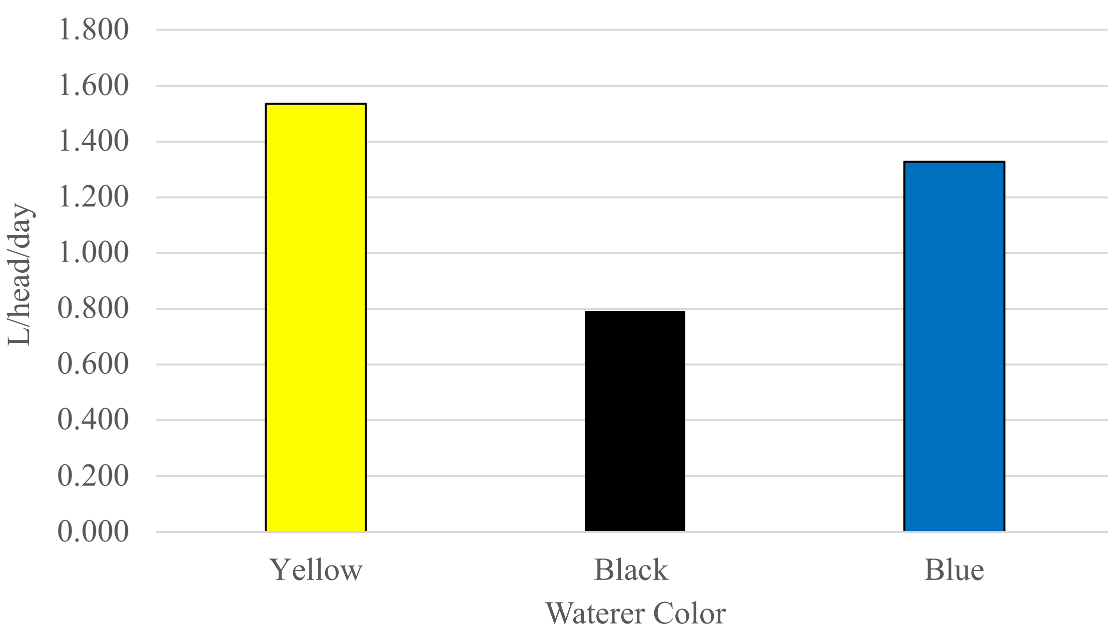


Figure 1: The average daily consumption from each waterer (L) per head of sheep based on color of the waterer. Based on statistical analysis ($P = 0.02$) the sheep consumed twice as much water from the blue and yellow waterers (1.327 L/head/day, 1.535 L/head/day) compared to the black waterer (0.7903 L/head/day). The pooled SEM is 0.148.

Based on data for the color preference, it is potentially beneficial to utilize colors, like blue or yellow, rather than black for waterers. A previous study concerning deer has demonstrated that deer and similar ungulates have photopigments that are sensitive to wavelengths corresponding to blue and yellow-green, which supports the idea that the sheep chose to drink from waterers based on the colors that they perceived as blue and yellow (VerCauteren and Pipas, 2003). The lack of consumption from black waterers may be due to the black waterers being dark and not allowing for sheep to adequately assess the amount of water within it. Sheep do have vision that is well acclimated to low light conditions, but the options of yellow and blue compared to the black leave the possibility that the darkness of the color still presents an effect on the sheep's willingness to drink from it (Jacobs et al., 1998).

A factor that may affect the way that sheep visualize the waterers is their relative brightness and luminance. Previous studies that focus on behavior-based color discrimination have been criticized for not accounting for the luminosity and brightness of the colors of their test materials (VerCauteren and Pipas, 2003). Brightness and luminosity, of course, are to be considered within the results of this study as well; however, a previous study utilized colors (green and gray) of different brightness in order to demonstrate that deer can distinguish between colors regardless of brightness differences, and they concluded that fallow deer use color to discriminate between items (Birgersson and Forkman, 2001). The findings of Birgersson and Forkman suggest that although brightness may have affected the sheep's choices in the present study, ungulates are still able to discriminate between colors with differences in brightness. Brightness and luminance still may be confounding factors within this experiment. The present study also focused primarily on the practicality of obtaining the desired colors rather than fully accounting for factors (i.e. brightness and luminance) that would not be sought after in production.

In the future, research should evaluate preferences in sheep regarding other opposite colors, such as red and green, and with complementary colors. These colors also can be compared to neutral colors such as black, white, and shades of gray in order to gauge a variety of color preferences.

Cleaning Frequency Preference

Sheep preferred ($P < 0.0001$) the waterer that was cleaned once per day (2.680 L/head/day) compared to waterers cleaned every seventh day (0.795 L/head/day). Sheep did not find waterers cleaned every fourth day (1.393 L/head/day) less preferable than waterers cleaned daily (2.680 L/head/day) nor more preferable than waterers cleaned every seventh day (0.795 L/head/day). Compared to the color preference experiment, the sheep did have a higher value for average daily water consumption, and this is most likely due to the addition of three ewes in the cleaning frequency trials. The ewes consume more water than the ram lambs, causing this number to be higher, so the average daily intake should not be compared between the color preference trials and the cleaning frequency trials.

The data for cleaning frequency revealed that sheep have a strong preference for clean water compared to soiled water. Although they found that the waterer cleaned on every fourth day was no more preferable than cleaning every seventh day and no less preferable than cleaning every day, it is beneficial to clean the waterers as often as possible. Cleaning the waterers every one to four days is ideal in order to encourage hydration. It may be difficult in terms of practicality for producers to clean their waterers daily, but it is important to monitor the waterers closely for feces, feed, bedding, and other remnants. Waterers may become dirty rather quickly

(Figure 3). Maintaining a schedule that meets or exceeds a biweekly schedule is optimal for the sheep.

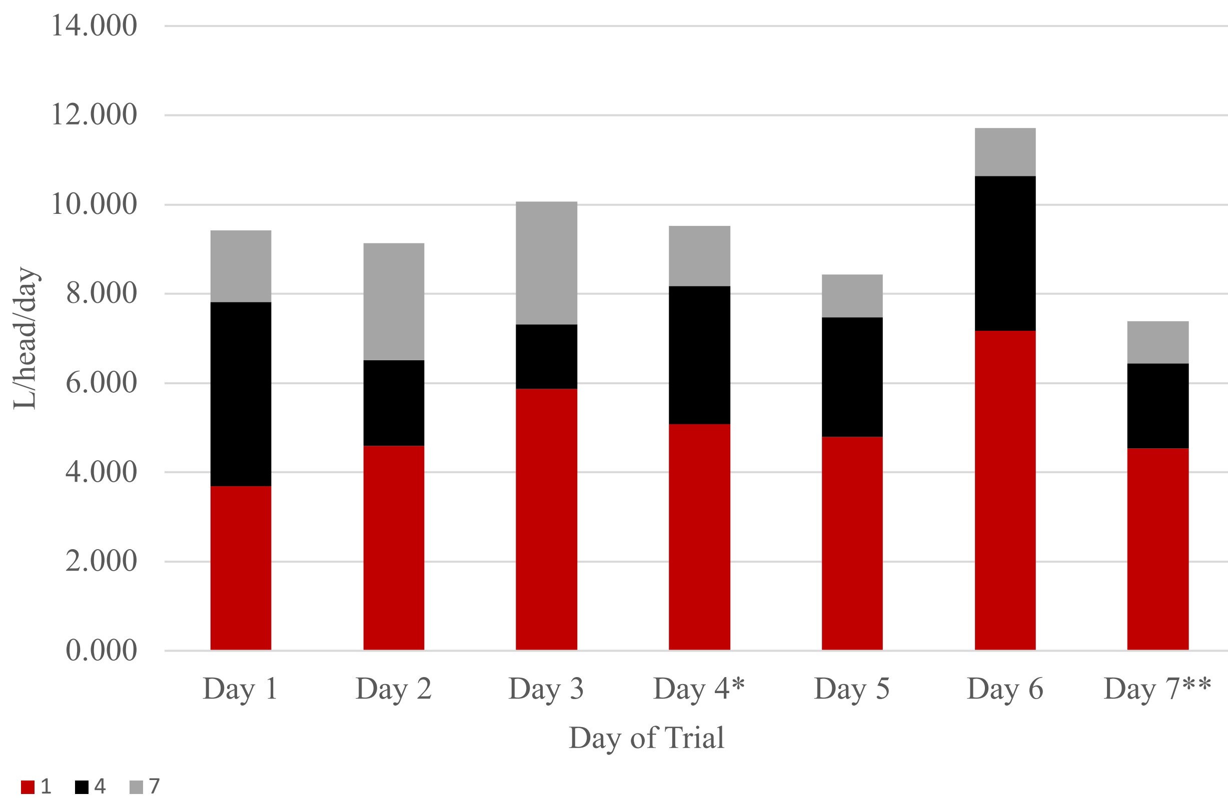
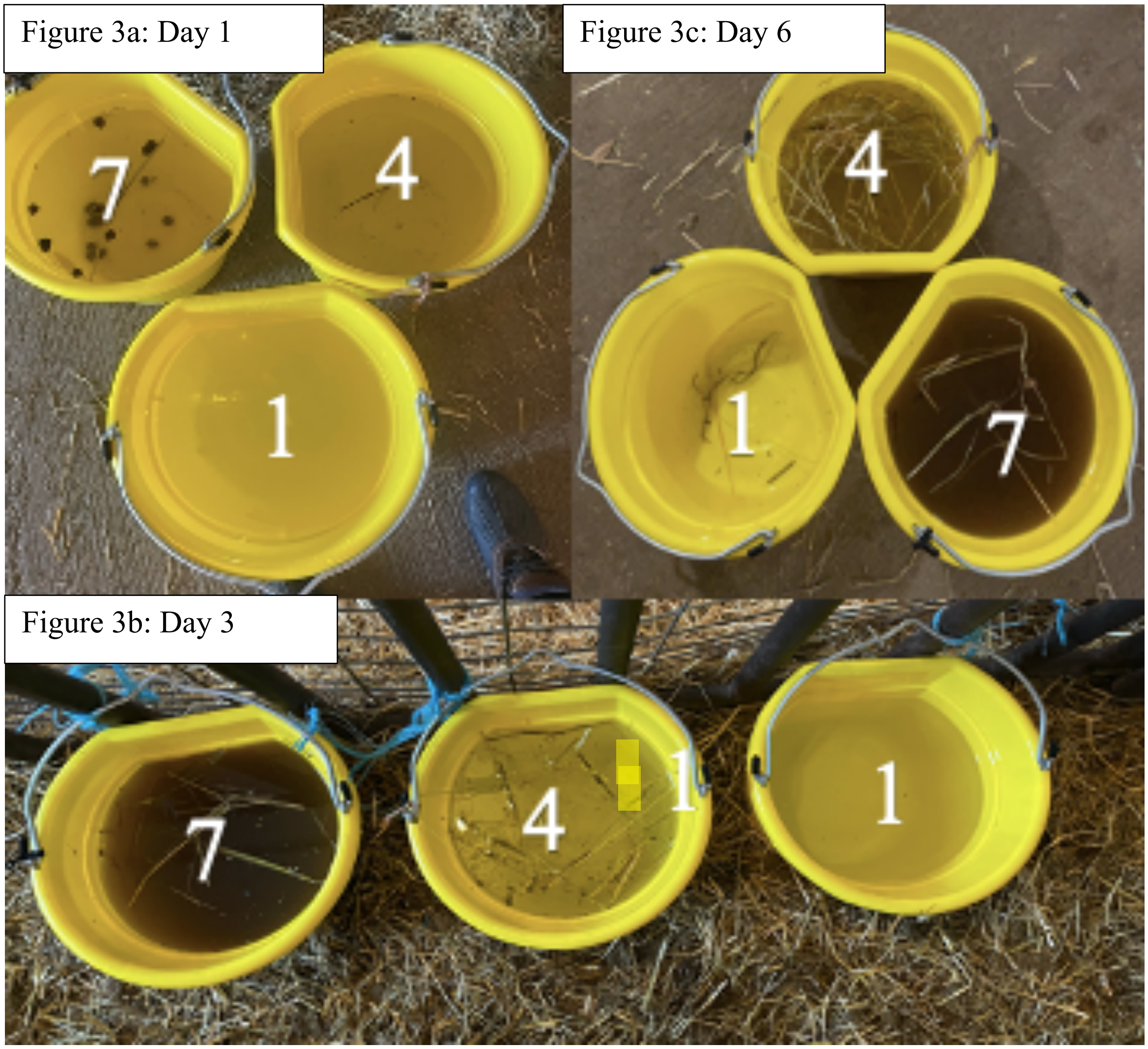


Figure 2: The proportion of average daily water consumption (in liters) consumed from each waterer based on cleaning schedule. 1: Cleaned daily; 4: Cleaned on the fourth day; 7: Cleaned on the seventh day. Based on statistical analysis ($P < 0.0001$), the sheep had a 3.5-fold increase in consumption from the waterer cleaned daily compared to the waterer cleaned every seventh day (2.680 L/head/day, 0.795 L/head/day). The sheep did not find that the waterer cleaned every fourth day (1.393 L/head/day) more preferable than the waterer cleaned every seventh day (0.795 L/head/day) nor less preferable than the waterer cleaned every day (2.680 L/head/day). The pooled SEM was 0.310. As time progresses, the proportion of consumption from the waterer cleaned daily increases while the proportion of consumption from waterer 4 decreases until day 4 and fluctuates until day 7, and consumption from waterer 7 generally decreases through day 7.



Figures 3a-c: The progression of soiling within the waterers of Pen 3. Waterers labeled **1** were cleaned daily, **4** were cleaned every fourth day, and **7** were cleaned every seventh day

When collecting data for the second week of cleaning frequency trials, the sheep continued to drink less water from the waterer cleaned every seven days despite the fact that the day 7 waterer had just been cleaned. On day 8, the sheep consumed 1.601 L from the waterer cleaned daily, 1.616 L from the waterer cleaned every fourth day, and 0.526 L from the waterer cleaned every seventh day. Again, the waterers were rotated in terms of location every 12 hours, so the sheep understood the day 7 waterer to be undesirable without having the cues of location or soiling to discriminate between the waterers. It is possible that the standard cleaning routine of removing the water, scrubbing with a bristled scrub brush, and rinsing the waterer was not sufficient in removing all of the scents or tastes of unpalatable factors of the water, like manure and other debris. It is worth exploring if incorporating a mild detergent or bleach would be beneficial in eradicating possibly aversive scents or tastes within the cleaning process. Of course, detergents and bleach may also provide new aversive scents or tastes and may be impractical for producers to implement into their cleaning schedule, but it is still another factor to be considered.

The data support that implementing a cleaning schedule in which the waterers are cleaned once per week revealed to be unacceptable, so later studies should utilize timelines that are shorter than weekly. This, for example may be comparing waterers cleaned daily versus every second day versus every third day. Testing various timelines will allow for a more concrete understanding of when waterers become contaminated enough to discourage drinking from them. It may also be beneficial for samples of the water after certain amounts of time to be sent to be analyzed for organic matter, salts, metals, and more. Determining each component's ratio within the water would allow researchers to determine an additional progression in soiling of the water. Data has demonstrated that salinity at 5,000-6,999 ppm is safe for adult animals but may cause problems in animals that are lactating, pregnant, young, or high producing, and ranges from 7,000+ may induce significant issues in the above animals and well as stressed individuals (Umar et al., 2014). 7,000 ppm equates to about 7% salinity, which is difficult to visually assess in water containers. Water may be at an unsafe level of salinity or other components without the producer knowing. A more pressing factor in contaminating water is that of organic compounds, such as algae, because water becomes unpalatable when these components are above 5ppm or greater than 0.0005% (Umar et al., 2014). Again, this is quite a small percentage of the water, making it practically impossible to assess these factors visually. Producers may be able to better determine when to clean out their waterers based on a daily progression of laboratory data.

Behavioral Observations

In analyzing behavioral data, sheep on average spent <2% of their time consuming from waterers during observations for both sets of trials. For the color trials, Sheep E only consumed from the black waterer during observations, indicating a possible individual preference, but it is not conclusive that this was solely due to the factor of color. All other sheep did not appear to exhibit an individual preference, likely due to lack of observations of the sheep consuming from the waterers. For the cleaning trials, >80% of recorded incidences of consumption from waterers were from the waterers cleaned daily. Sheep overall spent the majority of their time in the pen in a state of inactivity, eating, and manipulating items within their environments.

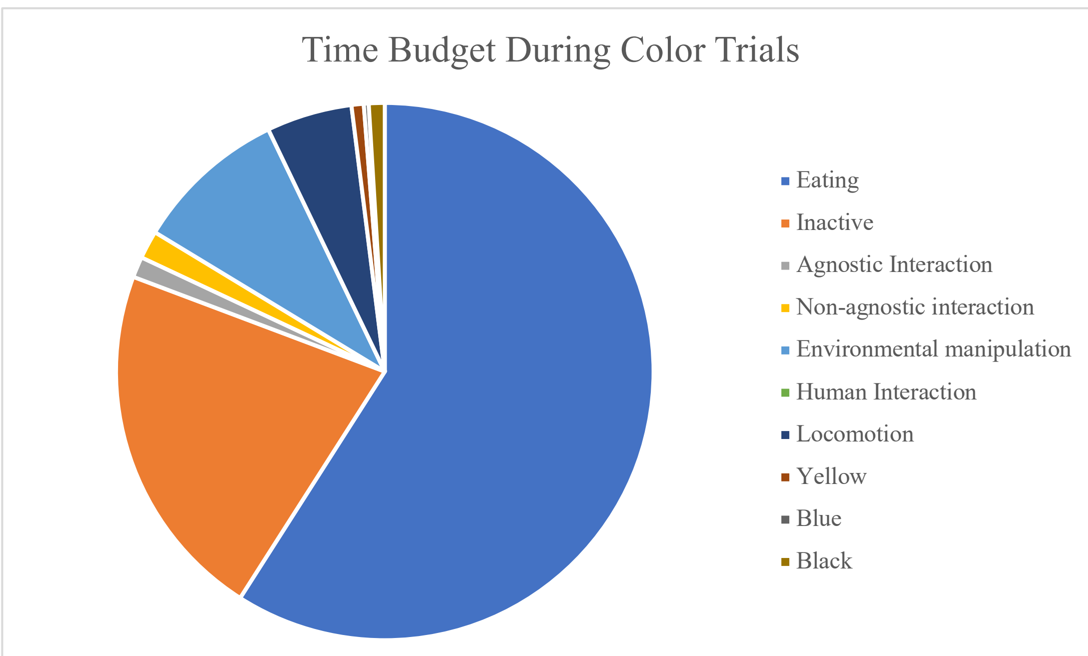


Figure 4: The percentage of time that sheep spent in the activities outline in the ethogram (Table 1) during the Color Preference trails. The sections labeled "Yellow," "Blue," and "Black" represent the instances in which sheep were drinking from the respective waterers. Sheep spent a total of about 2% of their time consuming from the waterers during observations.

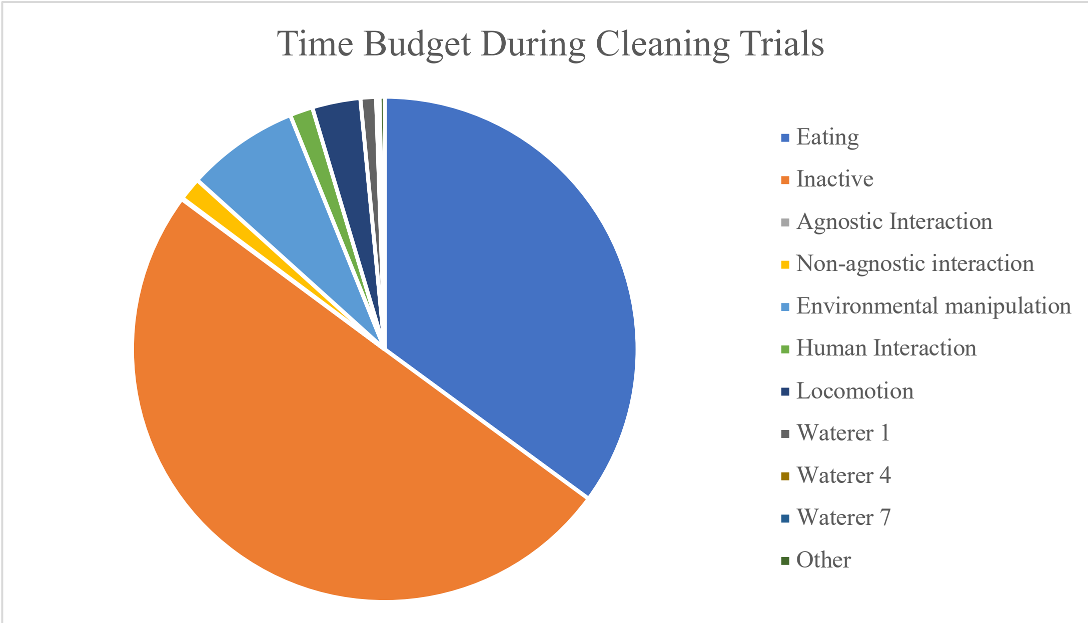


Figure 5: The percentage of time that sheep spent in the activities outlined in the ethogram (Table 1) during the cleaning frequency trials. The sections labeled "Waterer 1," "Waterer 4," and "Waterer 7" represent the instances in which sheep were drinking from the respective waterers. Sheep spent a total of about 1.2% of their time consuming from the waterers during observations.

For individual preferences, future behavioral studies should be expanded to include more times within the day, such as afternoon and mid-morning. During the late evenings and early mornings, the sheep did not interact with or consume from the waterers very often, making it difficult to definitively conclude if sheep have individual color preferences. If later studies considered more time periods, it is likely that there would be more indication regarding individual preferences because the studies would record more instances of the sheep consuming from the waterers.

CONCLUSIONS

This study specifically has implications for those who hand water their sheep, such as students that complete youth livestock exhibition competitions, like 4-H or FFA. Giving students such as these and other producers an understanding of the importance of cleaning their waterers frequently will have positive impacts both on the result of their projects and the welfare of the animals themselves. In demonstrating numerically and visually the amount of debris that accumulates in the waterers, the students are able to grasp that cleaning the waterers, for example, twice per week instead of once per week, is beneficial to their animals. In terms of color, this study encourages these students to purchase colors such as yellow or blue for their waterers rather than black.

It is undeniable that water is essential for the health and wellbeing of livestock species, and it is important for producers to be able to encourage water consumption in as many ways possible. The waterers themselves offer much potential in having controllable factors for producers, and the color of the waterer and the frequency in which it is cleaned are beneficial to consider. In order to best provide for the animal, producers should utilize colored waterers such as blue or yellow, and waterers should be cleaned every one to four days.

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